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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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[Title of the Invention]

METHOD AND APPARATUS FOR DIGITAL WATERMARKING DATA EXTRACTION, AND STORAGE MEDIUM STORING DIGITAL WATERMARK DATA EXTRACTION PROGRAM

[Claims]

1. A digital watermark data extraction method for extracting digital watermarked images repeatedly embedded with digital watermark data or extracting the digital watermark data from digital contents representing audio data by means of digital watermark embedding processing, the method comprises the steps of:

determining the most likely digital watermark sequence and its reliability by carrying out soft decisions of coding theory using a weight function; and

reconstituting digital watermark data on the basis of the most likely digital watermark sequence and the reliability.

2. The digital watermark data extraction method as claimed in claim 1, further comprising the steps of:

measuring in advance a deviation of distribution at the time of embedding and reading the digital watermarked contents data as the weight function; and

determining the most likely digital watermark sequence and its reliability by means of approximate distribution function.

3. The digital watermark data extraction method as claimed in claim 1, further comprising the step of:

determining the most likely digital watermark sequence and its reliability by means of distribution function predicting the deviation of distribution at the time of embedding and reading the digital watermarked contents data as the weight function.

4. The digital watermark data extraction method as claimed in claim 1, further comprising the steps of:

determining digital watermarked frequency component matrix after converting said the digital watermarked contents ;

determining the digital watermarked frequency sequence after selecting coefficient value from each frequency component matrix by a pseudo-random sequence;

generating weight sequence of the digital watermark by means of frequency component quantization width; and

reconstituting contents by means of statistical

processing of the weight sequence of said digital watermark.

5. A digital watermark data extraction apparatus for extracting digital watermarked images repeatedly embedded with digital watermark data or extracting the digital watermark data from digital contents representing audio data by means of digital watermark embedding processing, the apparatus comprises:

digital watermark sequence obtaining means for determining the most likely digital watermark sequence and its reliability by carrying out soft decisions of coding theory using a weight function; and

reconstituting means for reconstituting digital watermark data on the basis of the most likely digital watermark sequence and the reliability.

6. The digital watermark data extraction apparatus as claimed in claim 5, wherein said digital watermark sequence obtaining means further comprising::

the means for determining the most likely digital watermark sequence and its reliability by means of approximate distribution function after measuring in advance a deviation of distribution at the time of embedding and reading the digital watermarked contents

data as the weight function.

7. The digital watermark data extraction apparatus as claimed in claim 5, wherein said digital watermark sequence obtaining means further comprising:

means for determining the most likely digital watermark sequence and its reliability by means of distribution function predicting the deviation of distribution at the time of embedding and reading the digital watermarked contents data as the weight function.

8. The digital watermark data extraction apparatus as claimed in claim 5, wherein said digital watermark sequence obtaining means further comprising:

means for determining digital watermarked frequency component matrix after converting said the digital watermarked contents;

means for determining the digital watermarked frequency sequence after selecting coefficient value from each frequency component matrix by a pseudo-random sequence; and

means for generating weight sequence of the digital watermark by means of frequency component quantization width; and

said reconstituting means further comprising

the means of reconstituting contents by means of statistical processing of the weight sequence of said digital watermark.

9. A digital watermark data extraction program storage medium for extracting digital watermarked images repeatedly embedded with digital watermark data or extracting the digital watermark data from digital contents representing audio data by means of digital watermark embedding processing, the program comprises:

a digital watermark sequence obtaining process for determining the most likely digital watermark sequence and its reliability by carrying out soft decisions of coding theory using a weight function; and

reconstituting process for digital watermark data on the basis of the most likely digital watermark sequence and the reliability.

10. The digital watermark data extraction program storage medium as claimed in claim 9, wherein said digital watermark sequence obtaining process further comprising:

a process for determining the most likely digital watermark sequence and its reliability by means of

approximate distribution function after measuring in advance a deviation of distribution at the time of embedding and reading the digital watermarked contents data as the weight function.

11. The digital watermark data extraction program storage medium as claimed in claim 9, wherein said digital watermark sequence obtaining process further comprising:

a process for determining the most likely digital watermark sequence and its reliability by means of distribution function predicting the deviation of distribution at the time of embedding and reading the digital watermarked contents data as the weight function.

12. The digital watermark data extraction program storage medium as claimed in claim 9, wherein said digital watermark sequence obtaining process further comprising:

a process for determining digital watermarked frequency component matrix after converting said the digital watermarked contents;

a process for determining the digital watermarked frequency sequence after selecting coefficient value from each frequency component matrix by a pseudo-random

sequence; and

a process for generating weight sequence of the digital watermark by means of frequency component quantization width; and

said reconstituting process further comprising:

a process for reconstituting contents by means of statistical processing of the weight sequence of said digital watermark.

[Detailed Description of the Invention]

[Field of the Invention]

The present invention relates to a method and apparatus for digital watermarking data extraction, and storage medium storing digital watermark data extraction program, and more specifically to the method and apparatus for digital watermarking data extraction, and storage medium storing digital watermark data extraction program that are effective in realizing copyright protection for the multimedia production. According to the digital watermarking technique, sub-data is embedded in data contents without being noticed by a user by utilizing redundancy of data such as of an image and a sound. The digital watermarking technique is used for protecting a multimedia copyright by embedding copyright information, a user ID and the like as the sub-data in

secret, since it is difficult to separate the sub-data from the data contents.

It is easy to replicate or tamper fraudulently with multimedia production, and the easiness hinders an data content provider from sending data. In addition, some users may not use the data originated from the provider validly. Therefore, copyright protection is strongly needed for the multimedia production. The digital watermarking technique is effective in realizing the copyright protection. According to the digital watermarking technique, sub-data is embedded in data contents without being noticed by a user by utilizing redundancy of data such as of an image and a sound. The digital watermarking technique is used for protecting a multimedia copyright by embedding copyright information, a user ID and the like as the sub-data in secret, since it is difficult to separate the sub-data from the data contents.

[Prior Art]

Conventionally, the following digital watermarking techniques are proposed.

According to a technique proposed in Japanese patent application No.9-57516, "Image processing method and the apparatus," an image is subdivided into blocks larger than a 8×8 block size which is used for common

non reversible compression. Then, the size of the frequency coefficient which is obtained by discrete Fourier transform of the block is changed, the frequency coefficient being represented by a polar coordinate system and the size being a distance from the origin point of the polar coordinate system. As a result, sub-data can be read correctly even when the non-reversible compression is performed. In addition, the frequency coefficient is normalized within a range of predetermined values, is embedded, and read. In addition, weaker image processing is carried out on a complicated region as compared to a flat region. As a result, degradation of image quality which may be caused by embedding the sub-data can be suppressed and a tolerance to contrast changing is obtained. Further, as the value of the frequency coefficient to be changed becomes larger, the modification amount of the frequency coefficient becomes larger (the smaller the value is, the smaller the modification amount is) so as to suppress the deterioration of image quality more effectively. In addition, when subdividing an image into blocks, an image area which is smaller than one block is treated as one block by using an average pixel value and/or using a form symmetric with respect to a line repeatedly to compensate for the lacking image

area. Moreover, the sub-data is constituted from the whole image after weighting data of each block. As a result, the sub-data is read correctly even when the image is partly edited and/or the image with many flat parts is non-reversibly compressed.

In addition, according to a technique proposed in Japanese patent application No.9-164466, "Information embedding method, data reading method and the apparatus," when embedding data into motion pictures, data embedding is carried out to components of a relatively low frequency region. Further, frequency conversion is carried out with a block size larger than a block size used for data compression, and, then data embedding is carried out. Moreover, an original image is used when data is read. As a result, tolerance to data compression is obtained.

Other conventional techniques are proposed in Japanese patent applications No.8-305370, No.8-338769, No.9-9812, No.9-14388, No.9-109924, No.9-197003, No.9-218467 and No.10-33239. The digital watermark method is also called data hiding, finger printing steganography, image/sound deep encryption and the like.

Therefore, a digital watermark reading processing is to read the watermark sequence from the contents data that includes the digital watermark, and

them, the digital watermark data is reconstituted by performing statistical processing.

The conventional method is based on hard decisions on binary coding in code theory, which is shown in Fig.7. With respect to the watermark reading method based on hard decisions on binary coding, if almost all watermarked contents are embedded within a same range (shown as the diagonally shaded area), the performance is enough.

Here, an explanation is made regarding an operation of the conventional watermark reading apparatus based on Fig. 8, by using quantization width q[0], q[1],..., q[m-1]. For all integers

$$(0 \le i < \left\lfloor \frac{m}{n} \right\rfloor \cdot n),$$

a following process is carried out.

$$s[X][Y] \leftarrow \left\lfloor \frac{f'[i]}{q[i]} + \frac{1}{2} \right\rfloor \bmod 2$$

Here, $X = \left\lfloor \frac{i}{t} \right\rfloor$ and $Y = i \bmod t$.

In addition, $\lfloor x \rfloor$ represents a maximum number which does not exceed x and x mod y represents the remainder of x divided by y.

In the process for reconstituting digital watermark data by performing statistical processing on a digital watermark data sequence, for example,

$$W[j]=\begin{cases}1 & \sum_{k=0}^{t-1} v[j][k]\geq 0 \\ 0 & \sum_{k=0}^{t-1} v[j][k]<0\end{cases} \qquad (0\leqq j<n)$$

is used for the reconstitution.

[Object of the Invention]

However, according to the conventional watermark reading method, there is a following problem. Fig.30 shows a graph showing how MPEG-1 coding changes '1' data bit, specifically the graph shows occurrence frequency with respect to change amount of a DCT coefficient value by 1.5Mbps MPEG -1 coding. As shown in Fig.30, there is a case in which a considerable amount of watermarked data appears in the vicinity of the boundary of the reading bit value (which is shown in two dotted circles a and a'). As a result, it becomes difficult to separate noise from the watermarked data. In addition, there is a possibility that a digital watermark data value which is read becomes reversed with respect to the embedded digital watermark data.

In order to avoid the problem, two measures are conceivable. First measure is to raise the data diffusion rate by increasing the number of times the

data is embedded. Second measure is to increase the watermark embedding strength. Neither of these measures is a true solution because the first one may reduce the relative amount of embedded data and the second one may degrade the image. Accordingly, the present invention adopts soft decision rather than hard decision. In the following, a general description of the present invention will be given.

[Means to Solve the Problems]

Fig.1 is a diagram of a principle of the present invention (claim 1). As shown in the figure, a watermark sequence and the reliability is obtained in step 1, and, then, most likely digital watermark data is reconstituted based on the watermark sequence and the reliability in step 2.

The present invention (Claim 2) measures in advance a deviation of distribution at the time of embedding and reading the digital watermarked contents data as the weight function, and determines the most likely digital watermark sequence and its reliability by means of approximate distribution function.

The present invention (Claim 3) determines the most likely digital watermark sequence and its reliability by means of distribution function predicting the deviation of distribution at the time of embedding

and reading the digital watermarked contents data as the weight function.

The present invention (Claim 4) determines digital watermarked frequency component matrix after converting said the digital watermarked contents ;

determines the digital watermarked frequency sequence after selecting coefficient value from each frequency component matrix by a pseudo-random sequence;

generates weight sequence of the digital watermark by means of frequency component quantization width; and

reconstitutes contents by means of statistical processing of the weight sequence of said digital watermark.

Figure 2 is a diagram of a principle of the present invention.

The present invention (Claim 5) is a digital watermark data extraction apparatus for extracting digital watermarked images repeatedly embedded with digital watermark data or extracting the digital watermark data from digital contents representing audio data by means of digital watermark embedding processing, the apparatus comprising:

digital watermark sequence obtaining means 1 for determining the most likely digital watermark sequence and its reliability by carrying out soft decisions of

coding theory using a weight function; and

reconstituting means 2 for reconstituting digital watermark data on the basis of the most likely digital watermark sequence and the reliability.

The present invention (Claim 6) of the digital watermark sequence obtaining means 1 comprises:

the means for determining the most likely digital watermark sequence and its reliability by means of approximate distribution function after measuring in advance a deviation of distribution at the time of embedding and reading the digital watermarked contents data as the weight function.

The present invention (Claim 7) of the digital watermark sequence obtaining means 1 comprises:

means for determining the most likely digital watermark sequence and its reliability by means of distribution function predicting the deviation of distribution at the time of embedding and reading the digital watermarked contents data as the weight function.

The present invention (Claim 8) of the digital watermark sequence obtaining means 1 comprises:

means for determining digital watermarked frequency component matrix after converting said the digital watermarked contents;

means for determining the digital watermarked

frequency sequence after selecting coefficient value from each frequency component matrix by a pseudo-random sequence; and

means for generating weight sequence of the digital watermark by means of frequency component quantization width; and

said reconstituting means further comprising

the means of reconstituting contents by means of statistical processing of the weight sequence of said digital watermark.

The present invention (Claim 9) is a digital watermark data extraction program storage medium for extracting digital watermarked images repeatedly embedded with digital watermark data or extracting the digital watermark data from digital contents representing audio data by means of digital watermark embedding processing, the program comprises:

a digital watermark sequence obtaining process for determining the most likely digital watermark sequence and its reliability by carrying out soft decisions of coding theory using a weight function; and

a reconstituting process for digital watermark data on the basis of the most likely digital watermark sequence and the reliability.

The present invention (Claim 10) of said

digital watermark sequence obtaining process further comprises:

a process for determining the most likely digital watermark sequence and its reliability by means of approximate distribution function after measuring in advance a deviation of distribution at the time of embedding and reading the digital watermarked contents data as the weight function.

The present invention (Claim 11) of said digital watermark sequence obtaining process further comprises:

a process for determining the most likely digital watermark sequence and its reliability by means of distribution function predicting the deviation of distribution at the time of embedding and reading the digital watermarked contents data as the weight function.

The present invention (Claim 12) of said digital watermark sequence obtaining process further comprises:

a process for determining digital watermarked frequency component matrix after converting said the digital watermarked contents;

a process for determining the digital watermarked frequency sequence after selecting coefficient value from each frequency component matrix by a pseudo-random

sequence; and

a process for generating weight sequence of the digital watermark by means of frequency component quantization width; and

said reconstituting process further comprising:

a process for reconstituting contents by means of statistical processing of the weight sequence of said digital watermark.

Inferring from the frequency plot shown in Fig.9, it is easy to detect the digital watermark data sequence correctly if the repeating number of embedding is large enough. However, if a sufficiently large repeating number can not be obtained in actual practice, it becomes difficult to detect the desired digital watermark data sequence, thus filtering for watermarked content data becomes important. For example, concerning data which exists in the dotted circle in Fig.9, it is difficult to determine whether the data is watermarked content data or noise. Thus, it is needed to separate watermarked content data from noise effectively. For that purpose, according to the present invention, weights are assigned to the digital watermark data sequence by using soft decisions of coding theory. Specifically, distribution of watermarked content data is predicted, then digital watermark data is

reconstituted from a digital watermark data sequence to which a corresponding distribution value is added as the weight.

Accordingly, the watermarked content data can be separated from noise. Thus, error bits included in the digital watermark data sequence can be reduced, thereby a success rate of reading digital watermark data improves as compared with the above-mentioned conventional methods. According to the present invention, it becomes possible to see significant distribution bias in the watermark content data when the repeating number of embedding digital watermark data is small.

[Embodiments of the Invention]

Fig.3 shows a digital watermarking system of the present invention. In the system shown in Fig.3, digital watermark data 301 is embedded in digital data contents 303 by a digital watermark embedding apparatus 302, then, converted into watermarked digital data contents 304.

The watermarked digital data contents 304 are degraded to watermarked digital data contents 305 by compression or image processing while the watermarked digital data contents 304 are distributed by wireless or wire communication or by a packaged medium.

A digital watermark reading apparatus 306 reads a watermark sequence from the degraded watermarked digital data contents 305, and reconstitutes digital watermark data 307.

Here, an operation the digital watermark embedding apparatus 302 is explained.

Fig. 4 is a diagram for explaining the digital watermark embedding apparatus. In the figure, let the repeating number t of each bit of the digital watermark data be $t=\left\lfloor \frac{m}{n} \right\rfloor$, the frequency sequence be w[j],s[j][k]$\in$ {0,1} {0$\leqq$j<n,0$\leqq$k<t}.

In the process of diffusing the digital watermark data shown in Fig.2, for example, a process represented by s[j][k]=w[j] is carried out for all j and k, then, the digital watermark data (w[0],w[1],$\cdots$,w[n-1]) is transformed to the digital watermark data sequence s[0][0],s[0][1],$\cdots$,s[0][t-1],s[1][0],s[1][1], $\cdots$,s[1][t-1],s[n-1][0],s[n-1][1], $\cdots$,s[n-1][t-1].

In the watermark embedding process, quantization widths of frequency coefficients q[0],q[1], $\cdots$,q[m-1] are used, and for all integers $(0 \leq i < \left\lfloor \frac{m}{n} \right\rfloor \cdot n)$.

i) If $\left\lfloor \frac{f[i]}{q}+\frac{1}{2} \right\rfloor \bmod 2$ is equal to s[X][Y],

$$f'[i] \leftarrow \left\lfloor \frac{f[i]}{q}+\frac{1}{2} \right\rfloor \times q .$$

ii) If $\left\lfloor \frac{f[i]}{q}+\frac{1}{2} \right\rfloor \bmod 2$ is different from s[X][Y] and $\left\lfloor \frac{f[i]}{q}+\frac{1}{2} \right\rfloor$ is equal to $\left\lfloor \frac{f[i]}{q} \right\rfloor$,

$$f'[i] \leftarrow \left(\left\lfloor \frac{f[i]}{q}+\frac{1}{2} \right\rfloor +1 \right) \times q .$$

iii) If $\left\lfloor \frac{f[i]}{q}+\frac{1}{2} \right\rfloor \bmod 2$ is different from s[X][Y] and $\left\lfloor \frac{f[i]}{q}+\frac{1}{2} \right\rfloor$ is different from $\left\lfloor \frac{f[i]}{q} \right\rfloor$,

$$f'[i] \leftarrow \left(\left\lfloor \frac{f[i]}{q}+\frac{1}{2} \right\rfloor -1 \right) \times q .$$

Here, X=i/t and $Y = i \bmod t$. In addition, $\lfloor x \rfloor$ represents a maximum number which does not exceed x and x mod y represents the remainder of x divided by y.

Next, an operation regarding the digital watermark extraction apparatus 306 of the present invention is described.

Fig. 5 is a diagram describing the operation regarding the digital watermark extraction apparatus of the present invention.

As shown in the figure, in the digital watermark reading apparatus 306, when reading digital watermark, $v[X][Y] = weight\left(\frac{f'[Y]}{q[i]}\right) - Z \times \{(Z \bmod 2) - 1\}$, for all i $(0 \le i < \left\lfloor \frac{m}{n} \right\rfloor \cdot n)$, by using frequency coefficient quantization width q[0],q[1],$\cdots$,q[m-1]. Here, $X = \left\lfloor \frac{i}{t} \right\rfloor$, $Y = i \bmod t$, $Z = \left\lfloor \frac{f'[i]}{q[i]} + \frac{1}{2} \right\rfloor$. The function weight will be described later.

In the process for reconstituting digital watermark data by performing statistical processing on a digital watermark data sequence, for example,

$$W[j] = \begin{cases} 1 & \sum_{k=0}^{t-1} v[j][k] \ge 0 \\ 0 & \sum_{k=0}^{t-1} v[j][k] < 0 \end{cases} \qquad (0 \leqq j < n)$$

is used for the reconstitution.

[Embodiments]

In the following, a thirteenth embodiment of the present invention will be described. In the following example, the digital watermark reading process based on quantization in the digital watermark reading apparatus 106 will be described.

According to the thirteenth embodiment of the present invention, the digital watermark embedding

process is not changed from the conventional method. On the other hand, the digital watermark reading process is modified in order to improve digital watermark reading performance.

Here, let digital watermark data to be embedded in contents be $w_0, w_1, \cdots, w_{n-1}, w_i \in \{-1,1\}$, $0 \leqq i \leqq n-1$, and let a data set in which digital watermark data is embedded be $\{d_{0,0}, d_{0,1}, \cdots, d_{0,m-1}, d_{1,0}, d_{1,1}, \cdots, d_{1,m-1}, \cdots, d_{n-1,1} \cdots, d_{n-1,m-1}\}$. Let a quantization value used for quantize data $d_{i,j}$ $(0 \leqq i \leqq n-1, 0 \leqq j \leqq m-1)$ be $q_{i,j}$. Each bit data w_i of digital watermark data is embedded m times repeatedly. The digital watermark embedding process based on quantization is assumed to be a process in the following.

For all i and j $(0 \leqq i \leqq n-1,\ 0 \leqq j \leqq m-1)$

i) If $\left\lfloor \frac{d_{i,j}}{q_{i,j}} + \frac{1}{2} \right\rfloor \bmod 2$ is equal to w_i, $d_{i,j}$ is changed to $\left\lfloor \frac{d_{i,j}}{q_{i,j}} + \frac{1}{2} \right\rfloor \times q_{i,j}$.

ii) If $\left\lfloor \frac{d_{i,j}}{q_{i,j}} + \frac{1}{2} \right\rfloor \bmod 2$ is different from w_i and $\left\lfloor \frac{d_{i,j}}{q_{i,j}} + \frac{1}{2} \right\rfloor$ is equal to $\left\lfloor \frac{d_{i,j}}{q_{i,j}} \right\rfloor$, $d_{i,j}$ is changed to $\left(\left\lfloor \frac{d_{i,j}}{q_{i,j}} + \frac{1}{2} \right\rfloor + 1 \right) \times q_{i,j}$.

iii) If $\left\lfloor \frac{d_{i,j}}{q_{i,j}} + \frac{1}{2} \right\rfloor \bmod 2$ is different from w_i and

$\left\lfloor \frac{d_{i,j}}{q_{i,j}} + \frac{1}{2} \right\rfloor$ is different from $\left\lfloor \frac{d_{i,j}}{q_{i,j}} \right\rfloor$, $d_{i,j}$ is changed to $\left(\left\lfloor \frac{d_{i,j}}{q_{i,j}} + \frac{1}{2} \right\rfloor - 1 \right) \times q_{i,j}$.

Here, $\lfloor x \rfloor$ is a maximum number which does not exceed x. "x mod y" represents the remainder of x divided by y.

The present invention is not only applicable to the contents in which digital watermark data is embedded in the above-mentioned way but also applicable to other contents in which digital watermark data is embedded in other equivalent way.

In the following, the operation of the digital watermark reading apparatus 306 will be described in detail.

According to a following process, a watermark sequence $\{\tilde{w}_{0,0}, \tilde{w}_{0,1}, \ldots, \tilde{w}_{0,m-1}, \tilde{w}_{1,0}, \tilde{w}_{1,1}, \ldots, \tilde{w}_{1,m-1}, \ldots, \tilde{w}_{n-1,0}, \tilde{w}_{n-1,1}, \ldots, \tilde{w}_{n-1,m-1}\}$ is read from a set of data values $\{\tilde{d}_{0,0}, \tilde{d}_{0,1}, \ldots, \tilde{d}_{0,m-1}, \tilde{d}_{1,0}, \tilde{d}_{1,1}, \ldots, \tilde{d}_{1,m-1}, \ldots, \tilde{d}_{n-1,0}, \tilde{d}_{n-1,1}, \ldots, \tilde{d}_{n-1,m-1}\}$ of the watermarked digital data contents 105 in which digital watermark data is embedded. For all i and j ($0 \leqq i \leqq n-1$, $0 \leqq j \leqq m-1$)

$$n_{i,j} = \left\lfloor \frac{\tilde{d}_{i,j}}{q_{i,j}} + \frac{1}{2} \right\rfloor \quad \text{and}$$

$$\tilde{w}_{i,j} = weight\left(\frac{\tilde{d}_{i,j}}{q_{i,j}} - n_{i,j} \right) \times \{(n_{i,j} \bmod 2) \times 2 - 1\}.$$

Here, weight(x) (the domain is $-\frac{1}{2} \leq x \leq \frac{1}{2}$, and the range is equal to or more than 0. The function weight(x) will be called a weight function hereinafter) is a function which assigns weights to a read watermark sequence. By adopting a function which takes a large value in the vicinity of the central value (in the vicinity of the dotted vertical axis in Fig.5) and takes a small value in the vicinity of the boundary of the bit value (in the dotted circle in Fig.5), it becomes possible to separate effective watermark data sequence from noise.

Of course, it is possible to adopt a stretched weight(x) function in which the domain and the region is not limited. However, in the case, it is necessary to change the above mentioned formula to some extent.

Contents in which digital watermark data is embedded by digital watermark embedding processing is degraded due to data compression, media processing and the like. Thus, a watermark embedded data value $\tilde{d}_{i,j}$ deviates in some degree from a value $d_{i,j}$ of immediately after being embedded. Therefore, it is desirable to adopt a following function as the weight function. The function can be obtained such that the distribution of

the ratio $\frac{\tilde{d}_{i,j}-d}{q_{i,j}}$ of the amount of the deviation between $d_{i,j}$ and $\tilde{d}_{i,j}$ to the quantization value $q_{i,j}$ is predicted, and it is normalized with an appropriate scale for approximation. (There is no condition for the scale.)

For example, when assuming that digital watermark data is read from watermarked motion pictures which are MPEG compressed, the distribution shown in Fig.30 can be approximated by a Laplacian distribution. Thus, a Laplacian distribution of average 0 and variance 0.08 or a normal distribution of average 0 and variance 1/16 can be used effectively as the weighting function.

In addition, there is another method which uses another distribution function. The distribution function is formed so as to predict the error of the watermarked content data.

The digital watermark reading apparatus 106 reconstitutes and outputs digital watermark data $\tilde{w}_0, \tilde{w}_1, \ldots, \tilde{w}_{n-1}$ from read watermark sequence by applying, for example, $w_i = \begin{cases} 1 & \sum_{j=0}^{m-1} \tilde{w}_{i,j} \geq 0 \\ -1 & \sum_{j=0}^{m-1} \tilde{w}_{i,j} < 0 \end{cases}$

or Japanese patent application No.10-219236 ,"Embedding data coding method, the apparatus, computer readable medium storing embedding data coding program, read data

decoding method, the apparatus, computer readable medium storing read data decoding program, digital watermark data coding method, the apparatus, computer readable medium storing digital watermark coding program, digital watermark decoding method, the apparatus, computer readable medium storing digital watermark decoding program".

In addition, the above-mentioned process performed by the digital watermark reading apparatus 106 can be constructed by a program which can be stored in a computer readable medium such as a disk unit, a floppy disk, CD-ROM and the like.

This invention can be modified within the scope of the claims of the present application.

[Advantages of the Invention]

Experiments is performed in order to compare the method of the present invention and the conventional method of digital watermarking to motion pictures described in Japanese patent application No.9-164466.

As experimental conditions, a unit for digital watermark processing is assumed to be a 16 × 16 pixel and the conventional digital watermark data sequence reading is assumed to be $\tilde{w}_{i,j} = (n_{i,j} \bmod 2) \times 2 - 1$ on the basis of the assumptions of the above-mentioned embodiment. Watermark data is reconstituted as $\tilde{w}_0, w_1, \ldots, w_{n-1}$ for both

of the present invention and the conventional method.

As shown in Fig.7, it is recognized that digital watermark data reading success rate is improved in an MPEG-1 coded picture in any bit rates. The result shows the effectiveness of the present invention. Here, the digital watermark data reading success rate is obtained by dividing the number of correctly reconstituted digital watermark data by the total number of embedded digital watermark data.

According to the present invention, the digital watermark data sequence is separated from the noise so that error bits which are included in the digital watermark data sequence can be reduced, thereby the digital watermark data reading success rate is improved in comparison with the conventional method.

In addition, since weights are assigned to the digital watermark data sequence, the present invention is especially effective when the repeating number of watermark embedding is small.

The point of the present invention corresponding to the objective is applying soft decisions for the digital watermark reading process as opposed to the conventional method which uses hard decisions. The present invention is not limited to the above-mentioned process and can apply to other

equivalent digital watermarking method.

[Brief Description of the Drawings]

Fig.1 is a diagram showing a principle of the present invention;

Fig.2 is a constitutional diagram of the principle of the present invention;

Fig.3 is a constitutional diagram of a digital watermark system of the present invention;

Fig.4 is a diagram for explaining an operation of the digital watermark embedding apparatus;

Fig.5 is a diagram for explaining a digital watermark reading processing of the present invention;

Fig.6 is a diagram showing the digital watermark data reading success rate of the present invention and the conventional method;

Fig.7 is a diagram showing an overview of the conventional watermark embedding and reading processing;

Fig.8 is a diagram showing an overview of the digital watermark reading process of the conventional method;

Fig.9 is a diagram showing a deviation of distribution of the watermark sequence by MPEG-1 coding.

[Description of the Reference Numbers]

1 digital watermark sequence obtaining means

2 reconstituting means

301 digital watermark data

302 digital watermark embedding apparatus

303 digital data contents

304 watermarked digital data contents

305 degraded watermarked digital data contents

306 digital watermark reading apparatus

307 reconstitutes digital watermark data

[Name of the Document] Abstract

[Abstract]

[Object] Object of the present invention is to provide method and apparatus for digital watermarking data extraction, and storage medium storing digital watermark data extraction program that are possible to reduce error bits included in the digital watermark data sequence and thereby to improve a success rate of reading digital watermark data by separating digital watermarked contents data and noise in an processing of reading the digital watermark from the contents that are compressed or edited, without changing the data amount of the digital watermark and the digital watermark embedding processing.

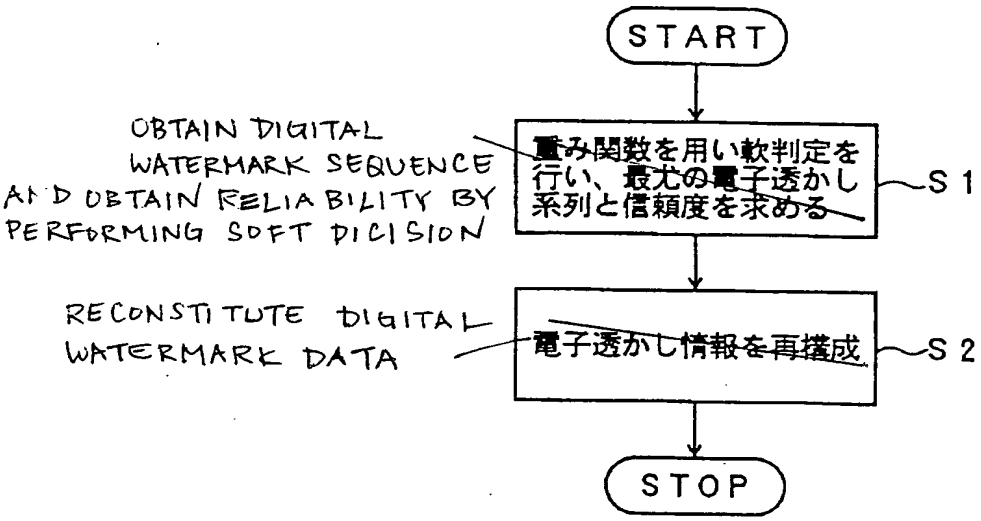
[Solution Means] The present invention determines the most likely digital watermark sequence and its reliability by carrying out soft decisions of coding theory using a weight function, and reconstitutes digital watermark data on the basis of the most likely digital watermark sequence and the reliability.

[Selected Figure] Fig. 1

【書類名】 図面 [Document] DRAWING

FIG.1 【図１】

A FLOWCHART SHOWING A PRINCIPLE OF THE PRESENT INVENTION
本発明の原理を説明するための図



【図2】FIG.2

A CONSTITUTIONAL DIAGRAM OF A PRINCIPLE OF THE PRESENT INVENTION

本発明の原理構成図

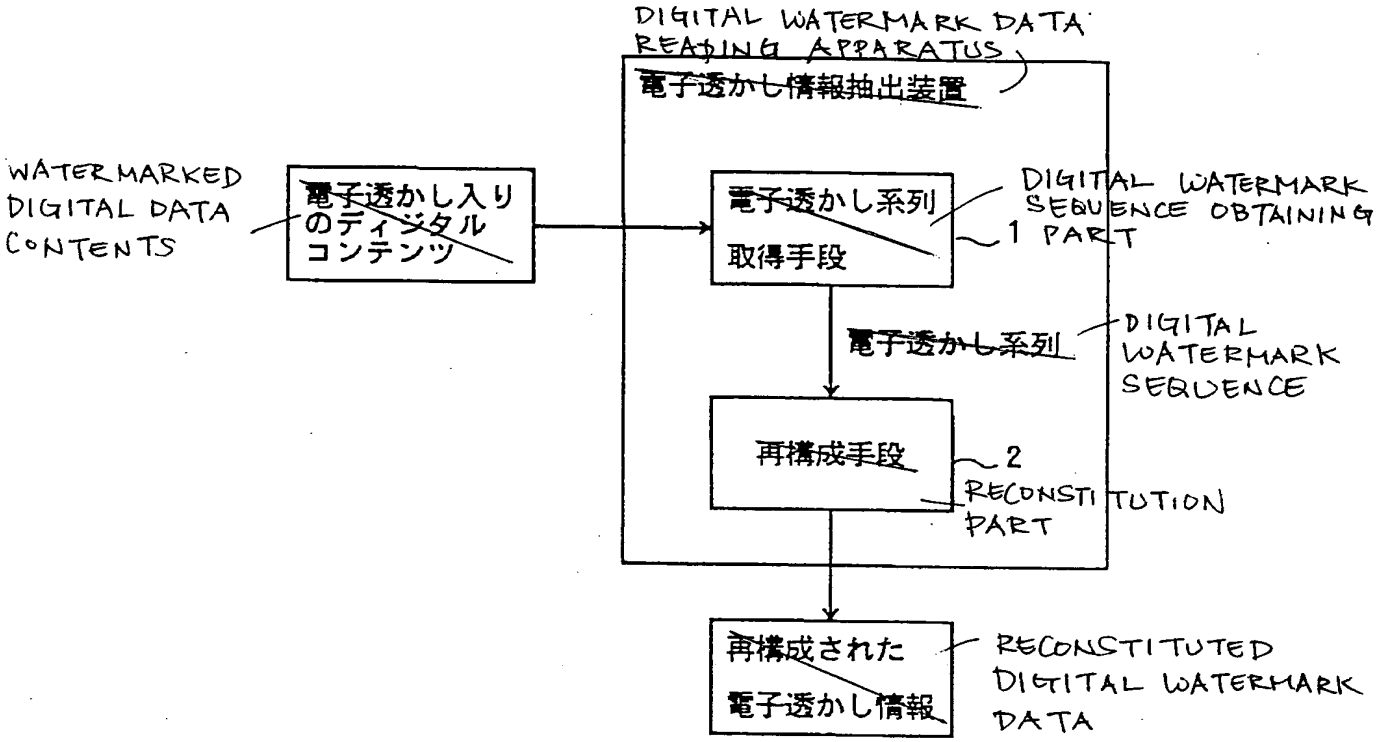


Fig.3【図３】

A FLOWCHART SHOWING A DIGITAL WATERMARK READING PROCESS ACCORDING TO THE PRESENT INVENTION

本発明の電子透かし読み取り処理を説明するための図

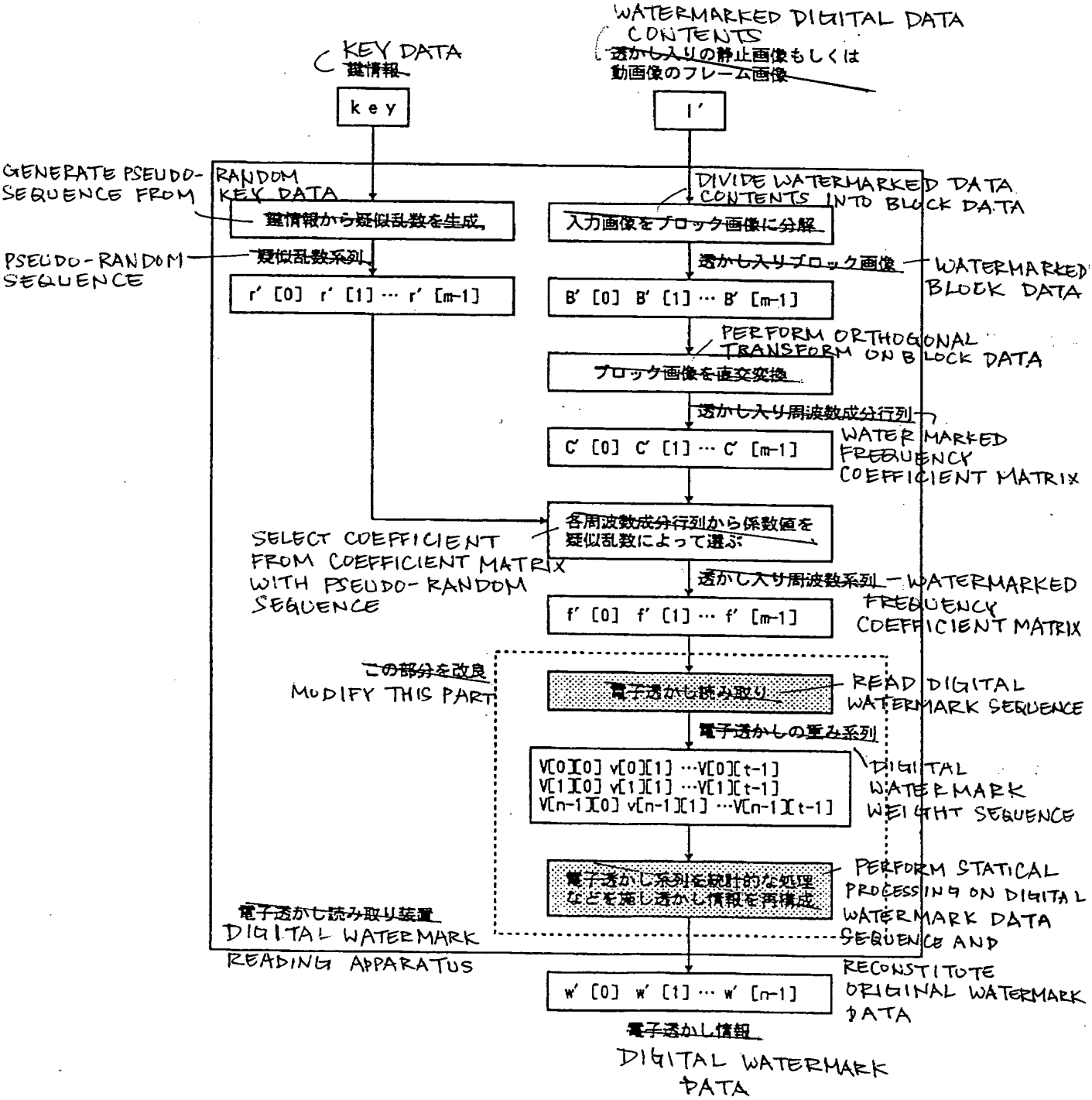
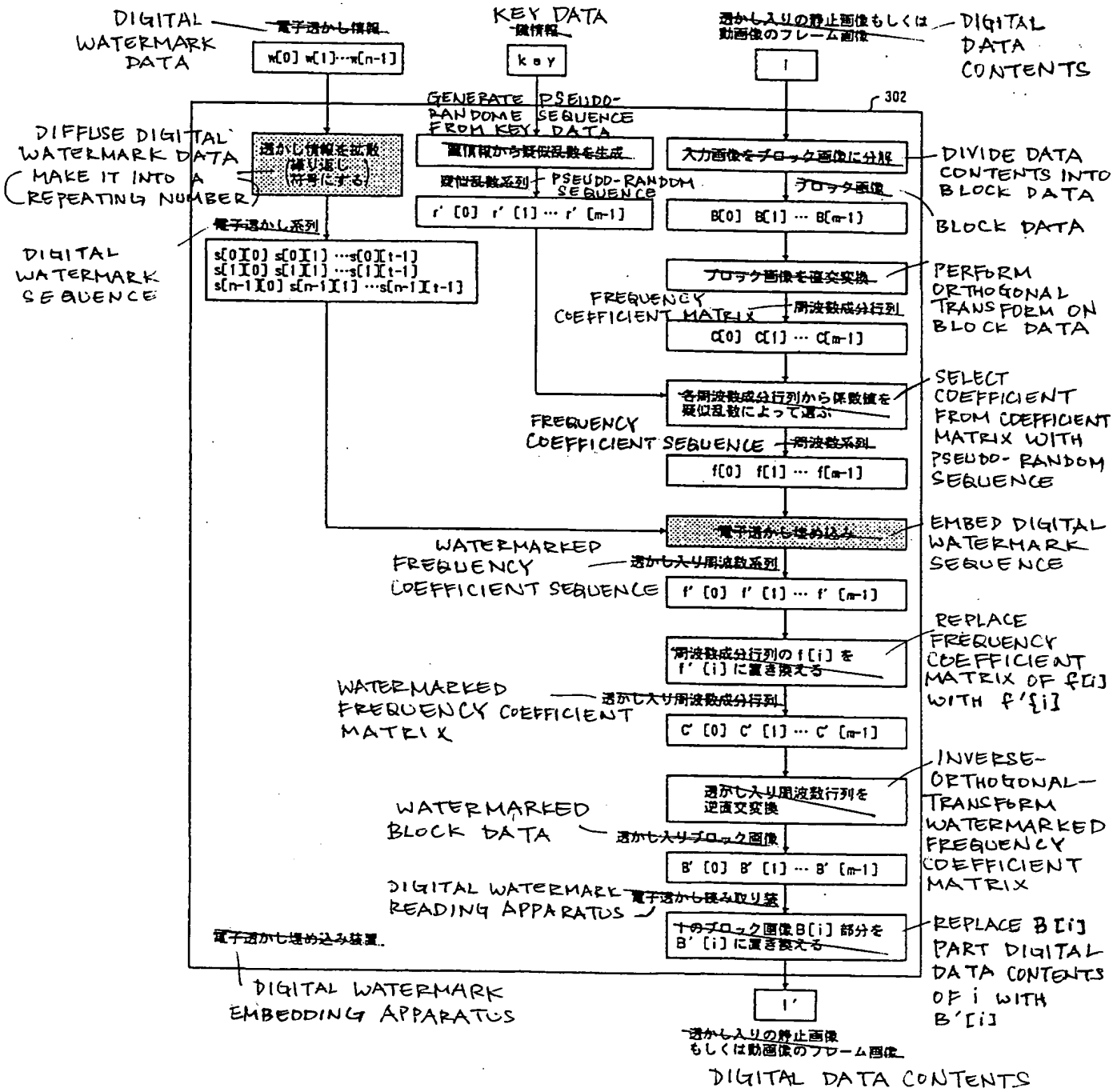


FIG. 4 【図4】 A DIAGRAM FOR EXPLAINING AN OPERATION OF THE DIGITAL WATERMARK EMBEDDING APPARATUS

電子透かし埋め込み装置の動作を説明するための図.



【図5】

FIG. 5

A CONSTITUTIONAL DIAGRAM OF A DIGITAL WATERMARKING SYSTEM OF THE PRESENT INVENTION

本発明の電子透かしシステム構成図

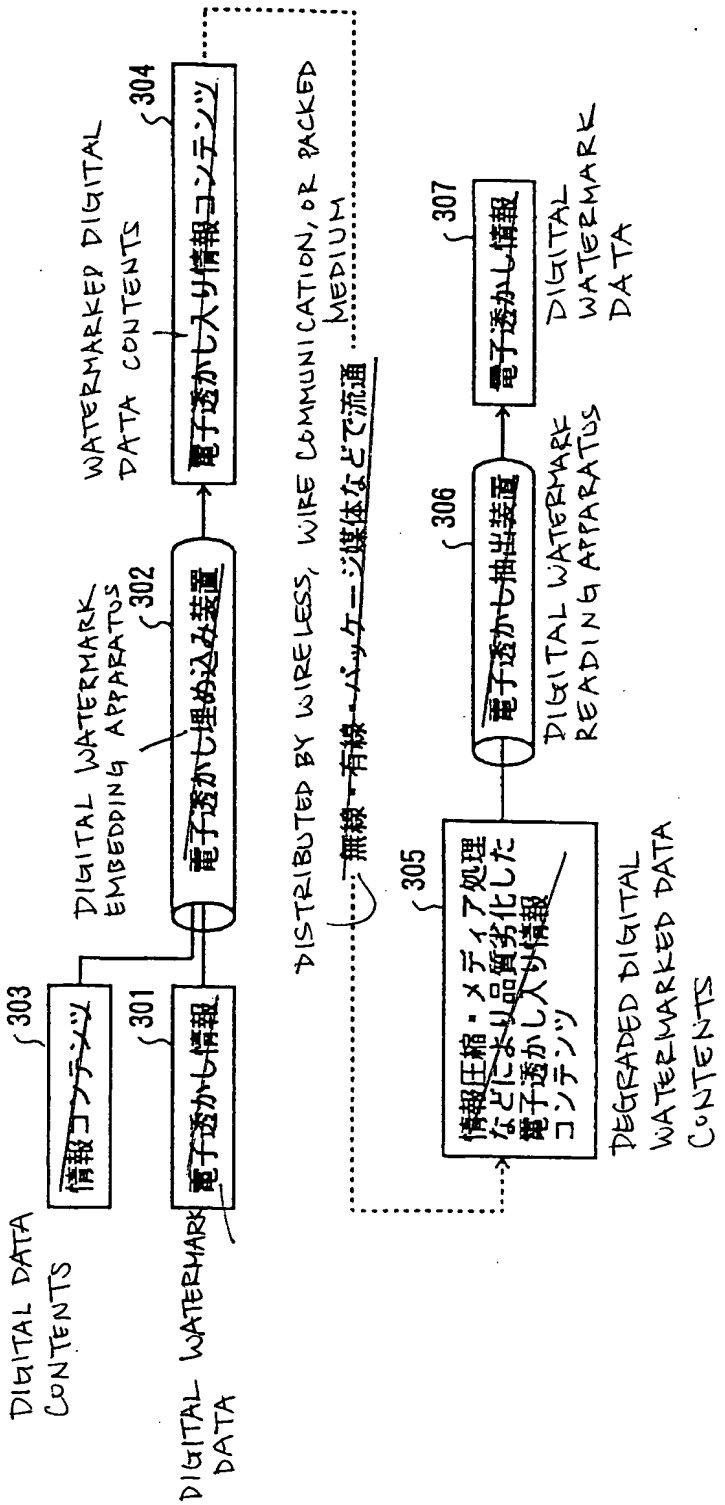


FIG.6 ~~【図6】~~ A DIAGRAM SHOWING THE RESULT OF COMPARISON OF DIGITAL WATERMARK DATA READING SUCCESS RATE BETWEEN A CONVENTIONAL READING METHOD AND THE PRESENT INVENTION.

~~本発明と従来の方法による~~

~~透かし情報読み取り成功率の比較を示す図~~

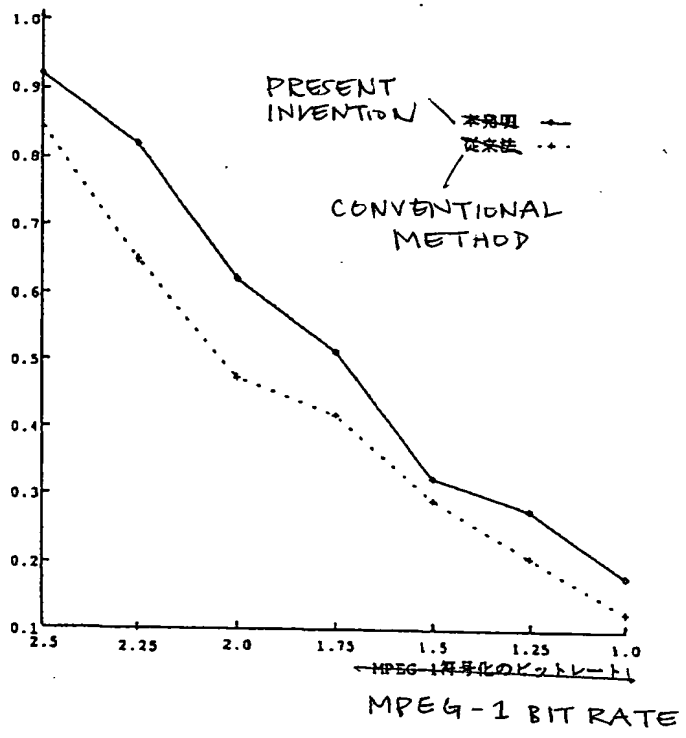


Fig.7【図7】

A DIAGRAM SHOWING A DIGITAL WATERMARK EMBEDDING AND READING PROCESS ACCORDING TO A CONVENTIONAL TECHNIQUE

~~従来の透かし埋め込みと読取処理の概要を示す図~~

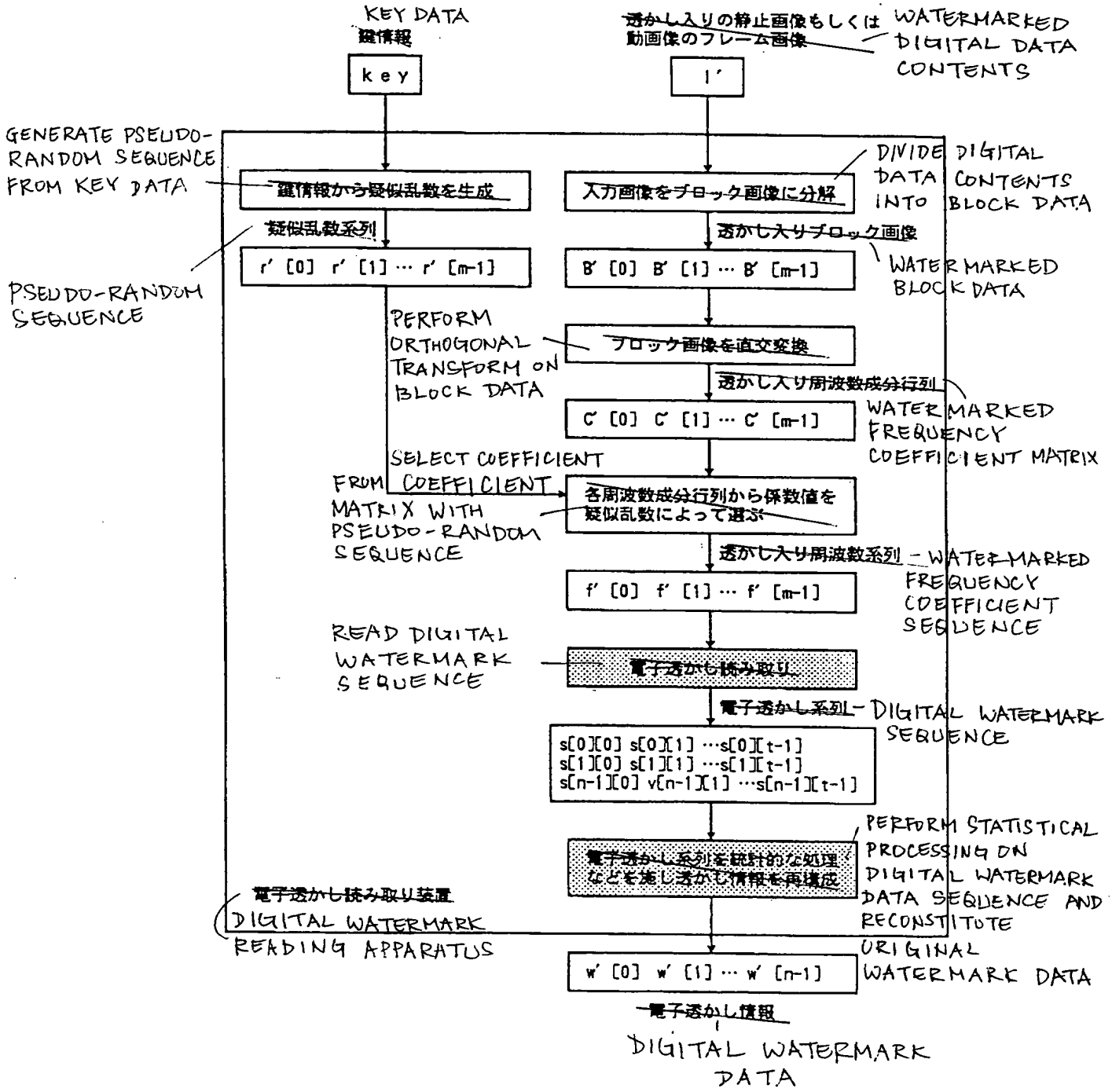
~~透かし埋め込み処理~~ WATERMARK EMBEDDING PROCESS

~~透かし読み取り処理~~ WATERMARK READING PROCESS

【図８】ＦＩＧ．８

A FLOWCHART SHOWING A DIGITAL WATERMARK READING PROCESS ACCORDING TO A CONVENTIONAL TECHNIQUE

従来の電子透かし読み取り処理の概要を示す図



【図9】 FIG. 9

A GRAPH SHOWING THE VARIANCE OF THE DISTRIBUTION OF WATERMARK DATA SEQUENCE BY MPEG CODING

MPEG符号化による透かし系列ずれ分布を示す図